ORGANIC MATTER QUALITY AND CARBON MINERALIZATION IN A HUMID TROPICAL ULTISOL UNDER RUBBER

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Soil organic matter quality and carbon mineralization in soils under immature rubber with *Pueraria phaseoloides*, banana, and pineapple and mature rubber were studied in a farmer's field in Kottayam district of Kerala state, India. It was found that water soluble carbon (WSC) and hot water extractable carbon (HWEC) were significantly higher in immature rubber with *Pueraria* and banana than the other two systems. Among the four systems studied, immature rubber with *Pueraria* had significantly higher particulate organic matter carbon (POMC) followed by mature rubber, immature rubber with pineapple and immature rubber with banana. Total carbon also showed significant variation among the systems and it decreased in the order immature rubber with *Pueraria* > immature rubber with banana > mature rubber > immature rubber with pineapple. An incubation experiment was also conducted to study the soil carbon mineralization in these systems. There was significant difference in carbon decomposition rate among the systems studied. The rate of carbon mineralization was in the order, immature rubber with *Pueraria* > immature rubber with banana ≈ immature rubber with pineapple > mature rubber. Carbon mineralization is positively influenced by WSC, HWEC and POMC and these parameters can be used as soil quality indicators in rubber based systems. The study indicated that vegetation and management practices in rubber plantation influenced soil organic matter quality and carbon mineralisation. Among the immature systems studied rubber-*Pueraria* system showed more nutrient supplying potential and mature rubber plantation showed carbon sequestration potential.

Key words: Carbon mineralization, Labile carbon, Rubber based systems, Soil quality

INTRODUCTION

Organic matter is an important component of soil which greatly influences soil quality. It has a key role in determining the soil fertility and plays an important role in the global carbon balance also. The quantity and quality of soil organic matter (SOM) may vary in arable systems depending on the crops and management practices (Wander, 2004). Soil organic matter can be broadly categorized to labile and recalcitrant pools depending on their turnover rates (Six *et al.*, 2002). Labile fraction mainly consists of easily oxidizable components such as carbohydrates, sugars, cellulose *etc.* which are palatable to microbes whereas, lignin and tannin type materials falls under the recalcitrant group which are resistant to decay (Heal *et al.*, 1997; Ghani

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et al., 2003). Land use or land management induced changes in soil organic matter status occur much more rapidly in the labile pools, such as particulate organic matter, soluble organic matter or microbial biomass than in the total organic carbon content (Gregorich *et al.*, 1994). It has been reported that higher quantity of organic matter need not necessarily maintain or increase crop yield (Ladha *et al.*, 2003). Brinson *et al.* (1998) reported that the nutrient availability in a system is more influenced by the size of the labile or active SOM fraction rather than the total quantity of SOM. Parton and Rasmussen (1994) also reported that the labile component of SOM plays the most important role in the short-term turnover of nutrients.

Chan *et al.* (2001) reported that different organic carbon fractions vary in their decomposition pattern and mineralization of soil organic matter plays the major role in available nutrient status in soil. With changes in the quality and quantity of SOM, the potential of a soil to supply or sequester nutrients is altered through the changes in mineralization - immobilization rates (Janssen and Persson, 1982). Decomposition of organic matter in a soil is mainly governed by soil microbes. However, the decomposition rate varies with the quality and physical availability of substrate to soil microbes (Raich and Tulekcioglu, 2000).

Establishment of legume covers (*Pueraria phaseoloids*/*Mucuna bracteata*) in immature rubber plantation is a recommended and commonly followed agronomic practice. Intercropping in immature rubber plantation is also a common practice and banana and pineapple are the popular intercrops. Since plant residues are the primary source of SOM in any system, the relative size and composition of SOM in the various rubber based systems may vary (Abraham, 2015). The agro management practices followed in different rubber based systems also varies and hence a variation in SOM quantity and decomposition rate is expected. Identifying and quantifying the suitable indicators that are sensitive enough to reflect the changes in SOM quality and quantity is very important to develop suitable nutrient management strategies for a sustainable nutrient management system. Understanding the decomposition kinetics of soil organic matter under different land use systems or management practices may provide useful information on the carbon stabilization potential of those systems also. Even though there are many reports available on the effect of intercrop / cover crop on soil properties in rubber growing soils (Jessy *et al.*, 1996; Philip *et al.*, 2005, and George *et al.*, 2012) information on labile fractions of organic carbon and soil carbon mineralization in different rubber based systems is limited. Hence, the present study was conducted to quantify labile carbon pools represented by water soluble carbon (WSC), hot water extractable carbon (HWEC) and particulate organic matter carbon (POMC), and their influence on soil carbon mineralization under different rubber based land use systems.

MATERIALS AND METHODS

The study was conducted in a farmer's field at Amayannoor, in Kottayam district of Kerala state,India, and the area experiences tropical humid climate and the soil belongs to Ustic Kandihumults (NBSS and LUP, 1999). The systems selected for the study were mature rubber, immature rubber cover cropped with *Pueraria phaseoloides*, immature rubber inter cropped with banana, and immature rubber inter cropped with pineapple. The fields were selected based on the observation that fairly good quantity of litter / crop residues was incorporated in the respective fields. Monoculture system of planting was followed in the mature rubber field (23 years after planting). The under-flora in the mature plantation was scanty and its litter turnover was negligible. The field is practically a no-tilled area and receives only chemical fertilizers for the last two decades. The field under immature rubber cover cropped with *Pueraria* was manually tilled for making pits to plant rubber and also for making platforms and the rubber plants were three years old. Thick litter layer of *Pueraria* was observed in the field. The field received only chemical fertilizers. The rubber field intercropped with banana was also manually tilled in the platform and inter-row areas during the planting time. The rubber plants in this field were two years old and received chemical fertilizers. However farm yard manure and chemical fertilizers were applied to banana. Also incorporation of crop residues of the previous planting had been noticed. The entire field under immature rubber intercropped with pineapple was tilled mechanically before planting. The rubber plants were two years old and received only chemical fertilizers while pineapple received both chemical fertilizers and farm yard manure. Litter or crop residues were observed to be very meager in this field compared to other studied systems.

Soil samples (0-10cm) were collected on a random basis from five different sites in each system. Three samples were collected from each sampling site and composited. The field moist samples were brought to the laboratory and a portion was sieved through a 2mm sieve and used for the estimation of water soluble carbon (WSC) and hot water extractable carbon (HWEC). The remaining portions were air dried, sieved (2mm) and used for other analyses. WSC and HWEC were determined, following the method as described by Ghani *et al.* (2003). Particulate organic matter was separated by following the method described by Camberdella *et al.* (2001). Total carbon, in 2 mm sieved soil and particulate organic matter carbon (2.00 - 0.053 mm) were estimated by dry combustion method using an automated elemental analyser (Leco Truspec CN). The total carbon estimated was organic carbon (OC) as the soils were very strongly acidic in nature and no inorganic forms of carbon can present in such acidic soil.

An incubation experiment was conducted to assess the mineralization rate of soil carbon under the different rubber based systems. Soil samples (2mm sieved, 20 g) were moistened to 60 per cent field capacity and incubated at 28°C in air -tight containers for 60 days and replicated five times. Evolved CO_2 was allowed to get absorbed in 10 ml of 1M NaOH kept in a vial placed inside the container. The vials were taken out at regular intervals *viz.* 7, 15, 30, 45, 60 days and titrated with 0.5 M HCl for quantifying evolved CO_2 (Lakaria *et al.*,2012).

Data generated was subjected to one - way analyses of variance (ANOVA) to find the significant difference if any among the four rubber based land use systems (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

These soils are sandy clay loam in texture and very strongly acidic (4.79) to strongly acidic (5.06) in nature. The data on water soluble carbon (WSC) and hot water extractable carbon (HWEC) (Table 1) indicated that the studied systems widely varied in organic matter quality. Water soluble carbon in the different systems varied from 35 (mature rubber) to 58 mg kg^{-1} (immature rubber with *Pueraria*). Immature rubber with *Pueraria* and banana recorded significantly higher WSC than the other two systems *viz*. mature rubber and immature rubber with pineapple. Similar trend was observed in HWEC also. It ranged from 378 (mature rubber) to 592 mg kg^{-1} (immature rubber with banana). Abraham (2015) reported low soluble carbon in mature rubber and rubber- pineapple systems than that in rubber-*Mucuna* / teak / forest systems. Water soluble carbon and HWEC accounted for 0.17 to 0.26 per cent and 1.84 to 2.74 per cent of total carbon, respectively. Leachates from plant litter and exudates from soil micro flora and roots are the primary sources of water soluble organic matter (Qualis *et al.*, 1991). Apart from the water soluble components, HWEC contain carbohydrates and N-containing compounds (amines and amides) also. Since plant litter and crop residues are the main sources of SOM, their composition and quantity influences the quality and quantity of SOM. When intercropped with rubber, the biomass additions through litter / crop residues was 5.5 t ha^{-1} in the case of *Pueraria* (Philip *et al.*, 2005) and 2.2 t ha^{-1} in the case of banana (Jessy *et al.*,1998). *Pueraria* litter was also reported to be having high cellulose content than rubber litter (Abraham and Chudek, 2008; Philip and Abraham, 2009). The higher litter / crop residue addition in *Pueraria* and banana systems coupled with their higher cellulose content might have contributed to the higher status of soluble forms of carbon in these two systems. The slow decomposition of pineapple residue than banana residue (Sudha, 2007) might have lead to low soluble carbon status in rubber-pineapple system.

The four systems differ significantly in their particulate organic matter carbon (POMC) levels (Table 1). It was significantly higher in immature rubber with *Pueraria* followed by mature rubber, immature rubber with pineapple and banana system. The particulate organic matter is a transitory pool of organic matter between fresh plant residues and humified organic matter. The higher POMC in immature rubber with *Pueraria* and mature rubber might be due to the higher litter input (5 to 6 t ha^{-1}) and minimum soil disturbance in these fields compared to the other two systems. The intense tillage and other soil disturbances in pineapple and banana systems might have affected the POMC content. Similar results were reported by Beare *et al.* (1994), Chan *et al.* (2001) and Saha *et al.* (2011) in other cropping systems.

There was significant variation in the total carbon content of the four systems (Table 1). It decreased in the systems as immature rubber with *Pueraria* > immature rubber with banana > mature rubber > immature rubber with pineapple. The organic matter status in a given soil depends on the quantity of litter input, decomposition

Table 1. **Carbon fractions and total carbon in different rubber-based systems**

Systems	WSC (mg kg^{-1})	HWEC (mg kg^{-1})	POMC (g kg^{-1})	TC (g kg^{-1})
Mature rubber	35.20	378	5.04	20.55
Immature rubber + *Pueraria*	58.00	556	6.11	23.40
Immature rubber + Banana	56.00	592	3.88	21.63
Immature rubber + Pineapple	37.00	398	4.39	19.36
SE	2.42	16.87	0.13	0.32
CD	7.26	50.57	0.39	0.97

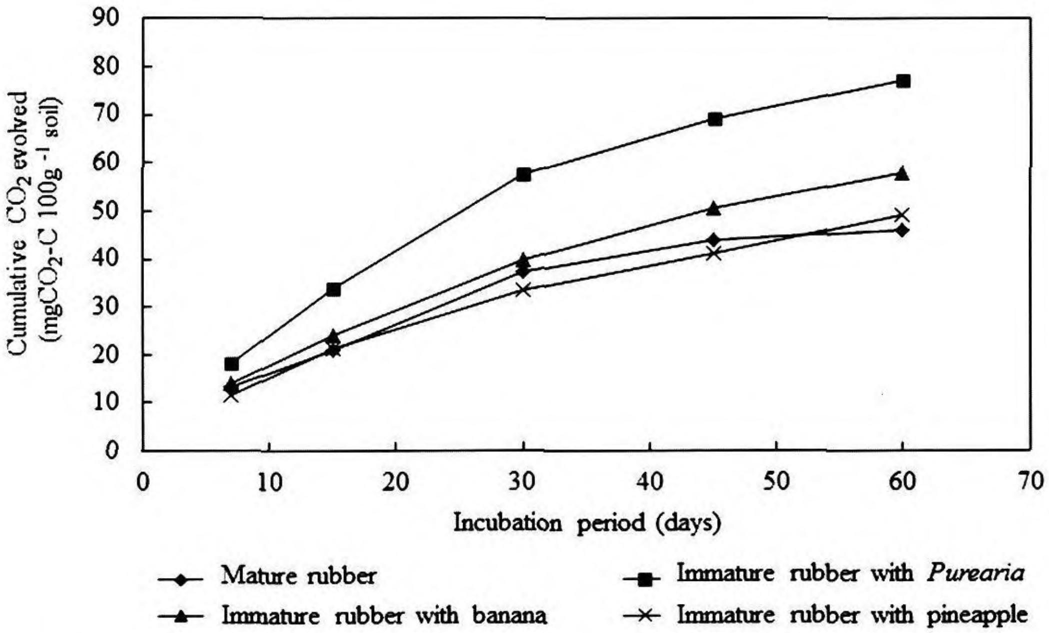

Fig. 1. Carbon mineralization in different rubber based systems

rate of organic residues and on the magnitude of soil disturbance. The higher litter input and faster decomposition of *Pueraria* (Philip and Abraham, 2009) might have resulted in higher carbon status in immature rubber with *Pueraria* compared to other systems. The intense tillage and lower residue input might have led to the lowest carbon status in immature rubber with pineapple system.

Figure 1 shows the mineralization pattern of soil carbon in the different systems. There was a rapid release of CO_2 in the initial phase in all the systems studied which are followed by a slow phase. The cumulative CO_2 evolution during 60 days of incubation from soils of the four systems ranged from 46 to 77 mg CO_2-C 100g^{-1} soil. Among the four systems studied, CO_2 evolution was highest in immature rubber with *Pueraria* followed by immature rubber with banana throughout the incubation period. But in the case of mature rubber, CO_2 evolution was more than that of rubber-pineapple system up to 45th day and then it became less than that of pineapple system.

The decomposability of the organic matter in different systems was estimated by considering the amount of carbon mineralized per unit weight of carbon in each system. It was found that, there was significant difference in total carbon mineralized (mg CO_2-C g^{-1} soil C) during the incubation period (Table 2). Immature rubber with *Pueraria* system recorded significantly highest carbon mineralization and the mature rubber the lowest. Immature rubber with banana and pineapple systems were comparable in carbon mineralization. The rate of carbon mineralization (mg CO_2-C g^{-1}soil C day^{-1}) was in the following order, immature rubber with *Pueraria* (0.55) > immature rubber with

Table 2. **Total carbon mineralization and rate of mineralization in different rubber-based systems**

Systems	Total C mineralized in 60 days ($mgCO_2$-C g^{-1} soil C)	Mineralization rate (mg CO_2-C g^{-1} soil C day^{-1})
Mature rubber	22.42	0.37
Immature rubber + *Pueraria*	32.92	0.55
Immature rubber + Banana	26.83	0.45
Immature rubber + Pineapple	25.38	0.42
SE	0.87	0.01
CD	2.60	0.04

banana (0.45) = immature rubber with pineapple (0.42) > mature rubber (0.37).

Microorganisms play a dominant role in SOM mineralization (Tate, 2000). Water soluble carbon is a palatable substrate for microorganisms and a large portion of it is readily decomposable (Davidson *et al.*, 1987). Presence of more soluble carbon fractions might have enhanced the carbon mineralization in the immature rubber with *Pueraria* system than the other three systems (Table 1). Kaur *et al.* (2008) also reported increase in mineralization with increase in WSC. The higher carbon mineralization rate in the immature rubber with pineapple system compared to the mature rubber system (Table 2) though these systems were having comparable soluble forms of carbon (Table 1) might be due to the effect of heavy tillage in the pineapple intercropped field. By tillage operations soil aggregates disrupts which enhances soil aeration and microbial interactions resulting in more decomposition of SOM. The higher mineralization in immature rubber with *Pueraria* system indicates its higher nutrient supplying potential than the other two systems with intercropping (banana and pineapple). This is beneficial especially in the initial growing phase of rubber when the nutrient requirements are more. The slow mineralization in soils under mature rubber indicates its carbon sequestration potential.

Correlation of carbon mineralization rate with soil carbon fractions is presented in Table 3. Water soluble carbon, HWEC and POMC showed significant positive correlation with carbon mineralization rate hence can be considered as good soil quality indicators.

Table 3. **Correlation between carbon fractions and carbon mineralization rate**

Soil carbon fraction	Carbon mineralization rate
WSC	0.72**
HWEC	0.76**
POMC	0.46*
WSC/TC	0.62**
HWEC/TC	0.56*
POMC/TC	0.11

** significant at 0.01 level
* significant at the 0.05 level

CONCLUSION

The study revealed that vegetation and management practices in rubber plantation influenced the quantity and quality of SOM. There was significant variation in total carbon among the systems and was highest in immature rubber with *Pueraria* and lowest in immature rubber with pineapple. The labile carbon fractions such as WSC and HWEC were comparable in rubber-*Pueraria* and rubber-banana systems and significantly higher than the other two systems.

Particulate organic matter carbon content was highest in rubber-*Pueraria* system. The SOM decomposition rate was also varying among the studied rubber based systems. The decomposition rate was significantly higher in the rubber-*Pueraria* system indicating the influence of labile carbon fractions on SOM decomposition. The management practices such as tillage was found to have an influence on SOM decomposition. The labile carbon fractions *viz.* WSC, HWEC and POMC can be considered as soil quality indicators in rubber based systems.

Since rubber-*Pueraria* system is conducive for faster SOM decomposition, higher rate of nutrient release can be expected. Hence, establishing *Pueraria* during the active growth phase of rubber is more beneficial compared to rubber-banana and rubber-pineapple systems. The slower decomposition of SOM in mature rubber favors carbon sequestration and is advantageous environmentally.

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